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<b>Motion Imagery Standards Board Engineering Guideline:</b>	<b>MISB EG 1002 20 May 2010</b>
<b>Profile 3: Range Image Metadata Set</b>	

## 1 Scope

This Engineering Guideline presents the KLV metadata format and structure necessary for the dissemination of an array of range data such as collected from the Standoff Precision Identification in Three-Dimensions (SPI-3D) LADAR sensor. This sensor is an example of an emerging capability to measure or extract range data aligned directly to EO/IR Motion Imagery. It collects its range data as an array of ranges (*i.e.* a range image) as well as an array of accuracy information for each range (*i.e.* an accuracy image). A key distinguishing characteristic of this sensor is that it collects data through the same physical aperture as a visible or infrared (depending on the mode of the passive sensor) sensor, which provides identical perspective geometry to the collected range image. In other words, the range and accuracy data is *co-boresighted* with the EO/IR sensor, they have the same perspective geometries. All range data being referred to in this document represents measured distances from the perspective center of the sensor and the point on the ground associated with the return in the range image plane.

The metadata structures of this Engineering Guideline are intended to allow for flexibility, bit-efficient packing of the data, and completeness needed for full field-of-view (FFOV) exploitation of the data. The intent of this Engineering Guideline is to be used in conjunction with *MISB EG 0801.2: Profile 1: Photogrammetry Metadata for Digital Motion Imagery* and all standards referenced therein. This Engineering Guideline is intended to complement *MISB EG 0801.2* and all referenced standards, where the information provided is unique and not contained elsewhere.

Furthermore, the intent of this EG is to describe the range and accuracy images that correspond to a co-boresighted passive image. In the absence of accompanying Motion Imagery, LADAR data sets **should not** use this EG; rather, the applicable LIDAR standards should be used to disseminate the data.

## 2 References

### 2.1 Normative Reference

*Mikhail, Edward M., James S. Bethel, and J. Chris McGlone. Introduction to Modern Photogrammetry. New York: John Wiley & Sons, Inc., 2001.*

*MISB RP 0701: Common Metadata System: Structure.*

*MISB Standard 0807.4: MISB KLV Metadata Dictionary*

*MISB RP 0603: Common Time Reference for Digital Motion Imagery Using Coordinated Universal Time (UTC).*

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*NIMA TR8350.2: Department of Defense World Geodetic System 1984, Its Definitions and Relationships with Local Geodetic Systems, 23 June 2004.*

*SMPTE 336M-2007: Data Encoding Protocol Using Key-Length-Value.*

*SMPTE RP 210.11: KLV Metadata Dictionary.*

### **2.2 Informative References**

*MISB EG 0104.6: Predator UAV Basic Universal Metadata Set.*

*MISB EG 0801.2: Profile 1: Photogrammetry Metadata Set for Digital Motion Imagery*

*MISB Standard 0601.4: UAV Datalink Local Data Set.*

*MISB Standard 0102.8: Security Metadata Universal and Local Sets for Digital Motion Imagery.*

*MISB RP 0604: Time Stamping Compressed Motion Imagery.*

*MISB RP 0605.2: Inserting Time Code and Metadata in High Definition Uncompressed Video.*

*MISB RP 0608.2: Motion Imagery Identification.*

### **2.3 Terms, Abbreviations, and Acronyms**

DOUBLE	IEEE Double precision floating point number
EG	Engineering Guideline
FFOV	Full Field-of-View
FILP	Floating Length Pack
FLOAT	IEEE Single precision floating point number
INT	IEEE Integer
KLV	Key-Length-Value
LDS	Local Data Sets
MISB	Motion Imagery Standards Board
NaN	Not-a-Number
RP	Recommended Practice
SMPTE	Society of Motion Picture and Television Engineers
SPI-3D	Standoff Precision Identification in Three-Dimensions
UINT	IEEE Unsigned Integer

## **3 Introduction**

Using the strict form of the Key-Length-Value formatting of the each metadata element for transmission is extremely inefficient. SMPTE 336M provides methods of increasing the bit-efficiency of a dataset, which include Truncation Packs (TP), Local Data Sets (LDS), and Fixed Length Packs (FILP). This Engineering Guideline makes use of these tools; specifically, the Local Data Set (LDS). A local data set maps the sixteen-byte Key assigned to a metadata parameter to a one-byte Tag within a Local Data Set. A further increase in bit-efficiency can be obtained by sending only the elements within the LDS which have changed from the default values. Truncation packs make use of a hierarchy of the parameters within the pack, where the highest priority elements are always sent and the elements with the least priority are only sent when needed. Also, the Truncation Pack has a fixed set of parameters placed in a fixed order,

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which allows for the length to be omitted. Fixed Length Packs contain a series of metadata elements with predetermined lengths, which can use a single key and length to identify many metadata values.

## 4 Range Image Metadata Set

### 4.1 Conventions

Unless otherwise noted, all keys represented by unsigned integers (UINTs) are packed representations of real numbers. See § 6 for the specific method of representing real numbers by integers for this EG.

The Version key (06.0E.2B.34.01.01.01.0E.01.02.05.04.00.00.00) is not a packed integer representation of a real number; its value is an integer.

The POSIX Microseconds key (06.0E.2B.34.01.01.01.03.07.02.01.01.01.05.00.00) is not a packed integer representation of a real number; per *MISB RP 0603: Common Time Reference for Digital Motion Imagery Using Coordinated Universal Time (UTC)*, its value is an integer.

The Image Rows Key (06.0E.2B.34.01.01.01.0E.01.02.02.06.00.00.00) and Image Column Key (06.0E.2B.34.01.01.01.0E.01.02.02.07.00.00.00) are not packed integer representations of real numbers; their values are integers.

### 4.2 Independent Keys

#### 4.2.1 POSIX Microseconds

The Range Image Local Data Set is the primary container for all the subsequent data. This LDS *shall* contain the time at which all range measurement data contained within was collected, or the time at which EO/IR data from which range was estimated, according to MISB RP 0603 using the POSIX Microseconds key.

Key Name:	POSIX Microseconds
Key Number:	06.0E.2B.34.01.01.01.03.07.02.01.01.01.05.00.00
Data Type:	UINT64
Data Format:	Bitwise mapping of 64 bit timecode into 8 bytes
Length:	8 bytes

See *SMPTE RP 210.11* for further details.

This key *shall* be present in the Range Image Local Data Set as the timestamp for the dataset.

#### 4.2.2 Version Number

The Range Image Local Data Set is the primary container for all the subsequent data. This LDS shall contain the version number of this document to indicate the version number for all data labeled within.

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Key Name:	Version
Key Number:	06.0E.2B.34.01.01.01.01.0E.01.02.05.04.00.00.00
Data Type:	UINT16
Data Format:	0d01 (For EG 1002.1; a future version EG 1002.2 would be 0d02)
Length:	2 bytes

This key shall be present in the Range Image Local Data Set as the version for the dataset.

### **4.2.3 Error Detection**

To help prevent erroneous metadata from being presented with video, it is required that a 32-bit cyclic redundancy check (CRC) be included in every the Range Image Local Data Set instance. The user has the option to include a CRC for each of the subordinate Local Data Sets or Floating Length Packs, which must be the last entry in each of the respective packs. The CRC is a running 32-bit sum through the entire LDS packet starting with the 16 byte Local Data Set key and ending with summing the length field of the checksum data item. If the calculated checksum of the received LDS packet does not match the checksum stored in the packet, the user must discard this packet as being invalid. The lost LDS packet is of little concern since another packet is available within reasonable proximity (in both data and time) to this lost packet.

Key Name:	CRC
Key Number:	06.0E.2B.34.01.01.01.01.0E.01.02.03.01.00.00.00
Data Type:	UINT16
Data Format:	
Length:	2 bytes

Note that this CRC-32 differs from the one commonly used in IP applications.

## **4.3 New Keys for the Range Image Metadata Set**

The following subsections describe the new Local Data Sets and Floating Length Packs used to define the Range Image Metadata Set.

### **4.3.1 Range Image Local Data Set**

This LDS is the primary set of data that describes the metadata for the Range Image. It consists of a series of descriptive values for the range image and the LDS or Floating Length Packs that describe the transformation, variance-covariance information, and the actual range and range-accuracy images.

This LDS contains a tag for an enumerated list named “Range Encoding.” Currently, three values exist in this list, which is given below in Table 1.

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Table 1: Enumerated List of Measurement Type Values

Value	Name
0	Other
1	Range Data
2	Plane Data
3	Height Data

The enumerated value is zero indexed, which is set to “Other.” The “Other” value is intended for range encodings that are not currently listed in Table 1. Future versions of this EG will have revisions on this table that are to include additional encodings. For instance, it is anticipated that quad-tree encodings are likely to prove useful for transmission efficiency. Current Range Encodings have the following semantics: Range Data, enumeration 1, consists of the ranges measured from the sensor to the terrain surface. Plane Data, enumeration 2, consists of the offset values from a plane described in this metadata set. Further description of the Plane Data can be found in Section 4.3.4. Height Data, enumeration 3, consists of the transformation of the range data into the ground plane, where the ground points are now represented with a height above the ellipsoid.

Each range image will contain three descriptive values used in the reconstruction of the range information: (1) the Minimum Range collected; (2) the depth of ranges collected or computed; and (3) the maximum accuracy value collected or computed. The minimum range is subtracted from all collected/computed ranges to help limit the amount of data needed to represent each range. The range depth describes the total depth of range values collected/computed, which range from zero (minimum range minus itself) to the range depth (when the minimum range is subtracted from the maximum range in the scene). The range depth is used in the integer remapping of the range data. The maximum accuracy helps bound the integer remapping of the accuracy information, which is always greater than zero.

Both the range and the range accuracy data have a reserved item to represent the Not-a-Number (NaN) value. (The integer representation of values with reserved bits is described in Section 6.1.) The NaN is used when no reliable range information exists at a particular pixel within the range image. This can occur when the sensor is set the begin collecting data with a specified depth, and the objects within the visible scene are either closer or farther than the desired range collection bounds. It essentially represents a range or illumination shadow.

, The uncertainty of the range at a pixel,  $P_i$ , is expressed as a variance (sigma squared), which is described in the following equation.

$$\sigma_{P_i}^2 = \sigma_{t_o}^2 + \sigma_i^2 \quad \text{Equation 1}$$

where  $\sigma_{t_o}$  is the one-sigma uncertainty of the minimum range of the sensor and handled as a bias common to all pixels in the range image; and  $\sigma_i$  is the one sigma uncertainty of the range at pixel

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i with respect to the minimum range. Hence, the uncertainty of the range difference between pixels i and j, expressed as a variance, is computed below.

$$\sigma_{\Delta R}^2 = \sigma_i^2 + \sigma_j^2 \quad \text{Equation 2}$$

(Recall that all instances of the term "range" implies a measured distance from the perspective center of the sensor and the point on the ground associated with the return in the range image plane.)

### 4.3.2 Visible-To-Range Image Transformation

The data collected using the SPI-3D sensor, the active sensor, is co-boresighted with the visible/infrared sensor, the passive sensor, through an identical aperture, but may be scaled differently and may be rotated somewhat from the visible/infrared sensor. Their co-boresightedness allows for a simplified transformation to be used between the two sensors, which is a plane-to-plane transformation. A plane-to-plane transformation, also known as an Eight-parameter transformation or a projective transformation, accounts for translation, rotation, projective differences, and scale differences between the two images.

The projective transformation (eight-parameter transformation) transforms the coordinates of the passive sensor into the active sensor (SPI-3D) through the following two equations. The variables in the following two equations are the line and sample coordinates in the active and passive images, labeled as  $L$  and  $S$ , respectively.

$$L_{Active} = \frac{(1-A) \cdot L_{Passive} + B \cdot S_{Passive} + C}{G \cdot L_{Passive} + H \cdot S_{Passive} + 1} \quad \text{Equation 3}$$

$$S_{Active} = \frac{D \cdot L_{Passive} + (1-E) \cdot S_{Passive} + F}{G \cdot L_{Passive} + H \cdot S_{Passive} + 1} \quad \text{Equation 4}$$

The initial value for all unknown parameters (A through H), the terms in the numerator and denominator, are all zero. This can help provide a form of compression or data reduction because *only the non-zero* parameters must be in the metadata stream. The default values imply the active and passive images are identical in orientation and scale. If all of the transformation parameters are zero, this information can be assumed to be the default and does not need to be transmitted.

The computation of the eight-parameters can be performed using a Least-Squares Estimation by identifying conjugate points or lines in the passive and active images, which is outside the scope of this documentation.

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In most exploitation scenarios, the passive image is the image where the measurements are made and the user is interested in the conjugate active pixel. There are some cases of exploitation where the inverse is needed, which can be computed without additional metadata elements. The inversion of Equation 3 and Equation 4 is given below in the following two equations.

$$L_{Passive} = \frac{((1-E) + F \cdot H) \cdot L_{Active} + (C \cdot H - B \cdot F) \cdot S_{Active} + (B \cdot F - C \cdot (1-E))}{(D \cdot H - G \cdot (1-E)) \cdot L_{Active} + (G \cdot B - H \cdot (1-A)) \cdot S_{Active} + ((1-A) \cdot (1-E) - D \cdot B)} \quad \text{Equation 5}$$

$$S_{Passive} = \frac{(G \cdot F - D) \cdot L_{Active} + ((1-A) - C \cdot G) \cdot S_{Active} + (D \cdot C - F \cdot (1-A))}{(D \cdot H - G \cdot (1-E)) \cdot L_{Active} + (G \cdot B - H \cdot (1-A)) \cdot S_{Active} + ((1-A) \cdot (1-E) - D \cdot B)} \quad \text{Equation 6}$$

### 4.3.3 Visible-To-Range Image Transformation Variance-Covariance Information

One goal of this Engineering Guideline is to provide a sensor model with sufficient information to perform all computations, such as uncertainty propagation. This Engineering Guideline provides standard-deviations and correlation coefficients needed to reconstruct the variance-covariance matrix of the transformation parameters. The transformation from the passive sensor to the active sensor is obtained through a Least-Squares Estimation, which gives the parameters and their accuracies. These accuracies are expressed through a variance-covariance matrix. This matrix is an eight-by-eight matrix (64 elements), which contains 36 unique elements (eight standard-deviation values and 28 correlation coefficients).

$$\begin{bmatrix} \sigma_A^2 & \sigma_{A,B} & \cdots & \sigma_{A,H} \\ \sigma_{B,A} & \sigma_B^2 & \cdots & \sigma_{B,H} \\ \vdots & \vdots & \ddots & \vdots \\ \sigma_{H,A} & \sigma_{H,B} & \cdots & \sigma_H^2 \end{bmatrix} = \begin{bmatrix} \sigma_A & 0 & \cdots & 0 \\ 0 & \sigma_B & \cdots & 0 \\ \vdots & \vdots & \ddots & \vdots \\ 0 & 0 & \cdots & \sigma_H \end{bmatrix} \begin{bmatrix} 1 & \rho_{A,B} & \cdots & \rho_{A,H} \\ \rho_{B,A} & 1 & \cdots & \rho_{B,H} \\ \vdots & \vdots & \ddots & \vdots \\ \rho_{H,A} & \rho_{H,B} & \cdots & 1 \end{bmatrix} \begin{bmatrix} \sigma_A & 0 & \cdots & 0 \\ 0 & \sigma_B & \cdots & 0 \\ \vdots & \vdots & \ddots & \vdots \\ 0 & 0 & \cdots & \sigma_H \end{bmatrix} \quad \text{Equation 7}$$

The standard-deviation values, represented by *sigma*, are always positive and the correlation coefficients, represented by *rho*, are always between -1 and +1. The transformation parameters must be flexible to accommodate any passive-active sensor combination, which limits their storage format to floating point numbers. Their standard-deviation values fall under a similar limitation because the upper bound of the value is unknown, which is also limited to a floating point number. The correlation coefficients, however, are bounded. This allows for integer remapping to be performed on these elements, which provides a form of data compression.

The assumed initial value for all sigma-values and correlation coefficients is identically equal to zero, which implies the transformation parameters are perfectly known. These values only need to be populated when their value is not equal to zero.

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### 4.3.4 Plane Reformatted Information

This Engineering Guideline gives the user the option to reformat the range data into a fitted plane. This plane representation of the range data can provide a form of compression, where the dynamic range of the values is reduced. The most benefit is gained when the collected data has a gradual slope with minimal perturbing features, such as buildings. Examples of gradually sloping terrain are: (1) flat, level ground viewed from an oblique angle; and (2) a hill or mountain side.

The two figures below highlight the benefit gained from reformatting the surface data using a plane. Figure 1 illustrates a two-dimensional surface with the red-line that has some character that could represent buildings or steep surfaces. The solid black line is a line that is fit to the surface data that minimizes the difference of the true surface from the line.

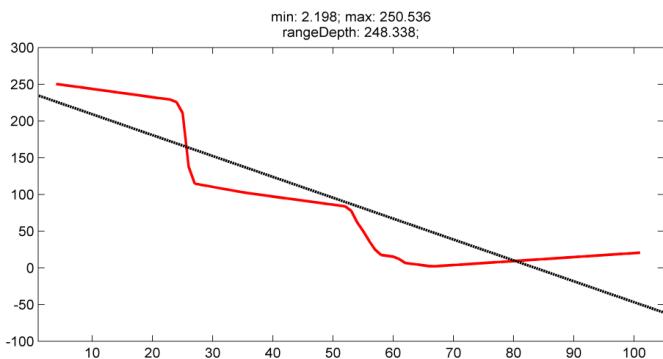


Figure 1: Two-dimensional terrain with a fitted surface

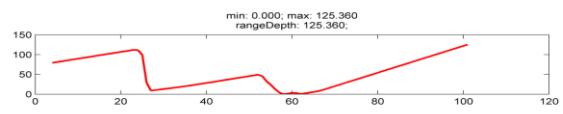
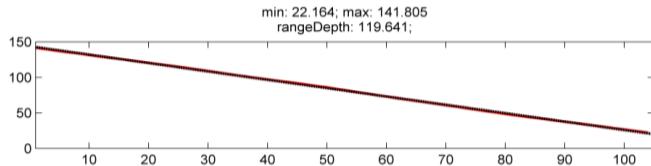


Figure 2: Reformatted surface with smaller dynamic range

When the data is reformatted as a difference from the plane with a minimum value of zero, as illustrated in Figure 2, the dynamic range of values is approximately 50% of the original dynamic range. This example would still require two-bytes to represent each value; however, the plane reformatted case would have a higher precision than the original data due to lower dynamic range of values. In the following case, Figure 3 shows a terrain in red that is gradually sloping down from left to right. Please note the fitted plane, the black line, plots similarly to the sloping terrain data, the red line, in Figure 3. This gives the appearance of a single black line. Its dynamic range of ranges is approximately 120 meters, where two-bytes are used to achieve sub-centimeter resolution.

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**Figure 3: Two-dimensional gradually sloping terrain**

Figure 4 illustrates the same surface after the plane-remapping has been applied. The dynamic range is now approximately two meters needing only one-byte to achieve sub-centimeter precision. This method has the ability to reduce the required storage by 50% while maintaining a similar level of resolution.



**Figure 4: Reformatted surface with smaller dynamic range**

The functional equation being used to map to the plane is a modified version of the generalized plane equation. The values of  $a$ ,  $b$ , and  $d$  are obtained by fitting the line-sample-range measurements of the collected data through a Least-Squares Estimator.

$$\Delta P = \frac{D_P(I_P - 1)}{2^{nb_P} - 2} \quad \text{Equation 8}$$

$$P_{DATA} = \Delta P + P_{OFF} \quad \text{Equation 9}$$

$$\Delta R = a \cdot L_{Active} + b \cdot S_{Active} + d + P_{DATA} \quad \text{Equation 10}$$

$$R = \Delta R + R_{min} \quad \text{Equation 11}$$

The residuals of the Least-Squares Estimation,  $P_{DATA}$ , give the values ranging from -0.5 to 0.5 multiplied by the dynamic range,  $D_P$ . These values are stored as integer values,  $I_P$ , formatted according to Section 6.1 using a specified number of bytes,  $nb_P$ . The range from the beginning of the gate,  $\Delta R$ , is then computed by applying the plane parameters. The range offset is then applied to these values and the slant range is computed for the pixel of interest. If one decides not to implement the plane-reformatting option, the default values are zero; then the residuals,  $P_{DATA}$ , are equal to the range within the gate,  $\Delta R$ .

### 4.3.5 Measured Data Format Floating Length Pack

Once the range data is reformatted using the fitted plane (or the original range data), the resulting values are mapped to integers. The bit-depth is chosen depending on the desired precision of the stored data. The *stored* value of zero will be reserved for the Not-a-Number (NaN) value, which indicates a range is not collected at this particular location. The remapping can be performed by inverting the process that will be described in Section 6.1. A field exists within this Floating Length Pack (FILP) that describes the return number of the measurements represented within this

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pack. The default value is one; however, this pack will be repeated  $N$  times as defined by “Total Returns” value in Table 2.

The resulting data, either the plane-reformatted data or the original range data, is then placed in a FILP. The FILP is a group of data that contains a few elements with constant length and another group of data that can have a varied length. If each element in the variable length portion has an identical length, the length of the variable length portion can be easily determined by subtracting the fixed length from the total length. A full description of this is contained in MISB RP 0701.

Figure 5 below gives a pictorial example describing how the measurement data is stored within the Floating Length Pack. The data is transmitted beginning at the upper-left corner of the array of data, listing the  $N$  elements within the row (*i.e.* samples) prior listing the next row of data. This is performed on each of the  $M$  rows within the array.

1	2	3	4	5	6	7	8	...	$N$
$N+1$	$N+2$	$N+3$	$N+4$	$N+5$	$N+6$	$N+7$	$N+8$	...	$2N$
$2N+1$	$2N+2$	$2N+3$	$2N+4$	$2N+5$	$2N+6$	$2N+7$	$2N+8$	...	$3N$
$3N+1$	$3N+2$	$3N+3$	$3N+4$	$3N+5$	$3N+6$	$3N+7$	$3N+8$	...	$4N$
$4N+1$	$4N+2$	$4N+3$	$4N+4$	$4N+5$	$4N+6$	$4N+7$	$4N+8$	...	$5N$
$5N+1$	$5N+2$	$5N+3$	$5N+4$	$5N+5$	$5N+6$	$5N+7$	$5N+8$	...	$6N$
$6N+1$	$6N+2$	$6N+3$	$6N+4$	$6N+5$	$6N+6$	$6N+7$	$6N+8$	...	$7N$
$7N+1$	$7N+2$	$7N+3$	$7N+4$	$7N+5$	$7N+6$	$7N+7$	$7N+8$	...	$8N$
⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮
$(M-1)N+1$	$(M-1)N+2$	$(M-1)N+3$	$(M-1)N+4$	$(M-1)N+5$	$(M-1)N+6$	$(M-1)N+7$	$(M-1)N+8$	...	$MN$

Figure 5: Order of elements within the Floating Length Pack

### 4.3.6 Measurement Accuracy Data Format Floating Length Pack

An identical process to that described in the previous section is used for the range data accuracy information. The measurement accuracy information is obtained directly from the sensor, and the estimate accuracy directly from the range algorithm. These can be remapped to integer values, reserving the zero value for NaN. The enumerated value described in Table 1 determines not only the encoding of the range data this EG represents, but it also defines the encoding of the accuracy being represented. The dynamic range of range accuracy values is from zero to the maximum accuracy value. The resulting range accuracy data is then placed in a second FILP.

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The data is recorded in the process described in Figure 5. A field exists within this FILP that describes the return number of the accuracies represented within this pack. The default value is one; however, this pack will be repeated  $N$  times as defined by “Total Returns” value in Table 2.

## **5 Tables**

The following subsection describe in tabular form the seven sets of data developed under this Engineering guideline. Table 2 provides the description of the overarching “container” that holds all relevant pieces to construct a range image for this active sensor. All of the following tables describe the elements that are contained within Table 2.

**UNCLASSIFIED****5.1 Range Image Local Data Set**

Table 2: Range Image LDS

Local Set Key		Name				
06.0E.2B.34.02.2B.01.01.0E.01.03.03.0C.00.00.00		Range Image LDS				
Constituent Elements						
Tag ID	Key	Name	Symbol/Notes	Units / Range	Format	Length
1	<b>06.0E.2B.34.01.01.03.07.02.01.01.05.00.00</b>	POSIX Microseconds	This Key Defined in SMPTE RP210.11	Integer $\mu$ s since 1 Jan 1970	UINT64	8
2	<b>06.0E.2B.34.01.01.01.0E.01.02.05.04.00.00.00</b>	Version	version	0d01	UINT16	2
3	06.0E.2B.34.01.01.01.0E.01.01.03.22.00.00.00	Range Encoding	rng encode_type	Enumerated	UINT8	1
4	06.0E.2B.34.01.01.01.0E.01.01.03.23.00.00.00	Minimum Range	min_range as $R_{\min}$ in Equation 11	Meters	DOUBLE	8
5	06.0E.2B.34.01.01.01.0E.01.01.03.24.00.00.00	Minimum Range Accuracy	sigma_min_range	Meters	FLOAT	4
6	06.0E.2B.34.01.01.01.0E.01.01.03.25.00.00.00	Range Depth	range_depth	Meters	FLOAT	4
7	06.0E.2B.34.01.01.01.0E.01.01.03.26.00.00.00	Maximum Accuracy Value	max_acc_val	Meters	FLOAT	4
8	06.0E.2B.34.01.01.01.0E.01.01.03.27.00.00.00	Total Number of Returns	n_total_returns	[0-255]	UINT8	1
9	<b>06.0E.2B.34.01.01.01.0E.01.02.03.01.00.00.00</b>	LDS Checksum	This Key Defined in MISB EG 0601	[0-65535]	UINT16	2
10	<b>06.0E.2B.34.02.2B.01.01.0E.01.03.03.0D.00.00.00</b>	Visible-To-Range Image Transformation LDS	As defined in Section 4.3.2	N/A	Table 3	N/A
51	<b>06.0E.2B.34.02.2B.01.01.0E.01.03.03.0E.00.00.00</b>	Visible-To-Range Image Covariance Information LDS	As defined in Section 4.3.3	N/A	Table 4	N/A
52	<b>06.0E.2B.34.02.2B.01.01.0E.01.03.03.0F.00.00.00</b>	Plane Reformatting Information LDS	As defined in Section 4.3.4	N/A	Table 5	N/A
53	<b>06.0E.2B.34.02.2B.01.01.0E.01.03.03.10.00.00.00</b>	Measured Data Format FILP	As defined in Section 4.3.5	N/A	Table 6	N/A
54	<b>06.0E.2B.34.02.2B.01.01.0E.01.03.03.11.00.00.00</b>	Range Accuracy Data Values FILP	As defined in Section 4.3.6	N/A	Table 7	N/A

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## 5.2 Visible-To-Range Image Transformation Local Data Set

Table 3: Visible-To-Range Image Transformation LDS

Local Set Key		Name				
06.0E.2B.34.02.2B.01.01.0E.01.03.03.0D.00.00.00		Visible-To-Range Image Transformation LDS				
Constituent Elements						
Tag ID	Key	Name	Symbol/Notes	Units / Range	Format	Length
1	06.0E.2B.34.01.01.01.0E.01.02.02.81.01.00.00	Line Equation Numerator-Line factor	A in Equation 3	Pixel/pixel	FLOAT	4
2	06.0E.2B.34.01.01.01.0E.01.02.02.81.02.00.00	Line Equation Numerator-Sample factor	B in Equation 3	Pixel/pixel	FLOAT	4
3	06.0E.2B.34.01.01.01.0E.01.02.02.81.03.00.00	Line Equation Numerator-Constant factor	C in Equation 3	Pixel	FLOAT	4
4	06.0E.2B.34.01.01.01.0E.01.02.02.81.04.00.00	Sample Equation Numerator-Line factor	D in Equation 4	Pixel/pixel	FLOAT	4
5	06.0E.2B.34.01.01.01.0E.01.02.02.81.05.00.00	Sample Equation Numerator-Sample factor	E in Equation 4	Pixel/pixel	FLOAT	4
6	06.0E.2B.34.01.01.01.0E.01.02.02.81.06.00.00	Sample Equation Numerator-Constant factor	F in Equation 4	Pixel	FLOAT	4
7	06.0E.2B.34.01.01.01.0E.01.02.02.81.07.00.00	Denominator-Line factor	G in Equation 3 and Equation 4	Pixel/pixel	FLOAT	4
8	06.0E.2B.34.01.01.01.0E.01.02.02.81.08.00.00	Denominator-Sample factor	H in Equation 3 and Equation 4	Pixel/pixel	FLOAT	4
9	06.0E.2B.34.01.01.01.0E.01.02.03.01.00.00.00	LDS Checksum	This Key Defined in MISB EG 0601	[0-65535]	UINT16	2

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### 5.3 Visible-To-Range Image Covariance Information Local Data Set

Table 4: Visible-To-Range Image Covariance Information LDS

Local Set Key		Name				
		Visible-To-Range Image Covariance Information LDS				
Constituent Elements						
Tag ID	Key	Name	Symbol/Notes	Units / Range	Format	Length
1	<b>06.0E.2B.34.02.2B.01.01.0E.01.03.03.0E.00.00.00</b>	Sigma Line Equation Numerator-Line factor	Sig_A in Equation 7	Pixel/pixel	FLOAT	4
2	<b>06.0E.2B.34.01.01.01.0E.01.02.02.81.0A.00.00</b>	Sigma Line Equation Numerator- Sample factor	Sig_B in Equation 7	Pixel/pixel	FLOAT	4
3	<b>06.0E.2B.34.01.01.01.0E.01.02.02.81.0B.00.00</b>	Sigma Line Equation Numerator-Constant factor	Sig_C in Equation 7	Pixel	FLOAT	4
4	<b>06.0E.2B.34.01.01.01.0E.01.02.02.81.0C.00.00</b>	Sigma Sample Equation Numerator-Line factor	Sig_D in Equation 7	Pixel/pixel	FLOAT	4
5	<b>06.0E.2B.34.01.01.01.0E.01.02.02.81.0D.00.00</b>	Sigma Sample Equation Numerator- Sample factor	Sig_E in Equation 7	Pixel/pixel	FLOAT	4
6	<b>06.0E.2B.34.01.01.01.0E.01.02.02.81.0E.00.00</b>	Sigma Sample Equation Numerator-Constant factor	Sig_F in Equation 7	Pixel	FLOAT	4
7	<b>06.0E.2B.34.01.01.01.0E.01.02.02.81.0F.00.00</b>	Sigma Denominator-Line factor	Sig_G in Equation 7	Pixel/pixel	FLOAT	4
8	<b>06.0E.2B.34.01.01.01.0E.01.02.02.81.10.00.00</b>	Sigma Denominator-Sample factor	Sig_H in Equation 7	Pixel/pixel	FLOAT	4
9	<b>06.0E.2B.34.01.01.01.0E.01.02.02.81.11.00.00</b>	Correlation Coefficient (CC) Line_Num_Line - Line_Num_Samp	CC A - B in Equation 7	[-1 ... +1]	UINT16	2
10	<b>06.0E.2B.34.01.01.01.0E.01.02.02.81.12.00.00</b>	CC Line_Num_Line - Line_Num_Const	CC A - C in Equation 7	[-1 ... +1]	UINT16	2

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11	<b>06.0E.2B.34.01.01.01.0E.01.02.02.81.13.00.00</b>	CC Line_Num_Line - Samp_Num_Line	CC A - D in Equation 7	[-1 ... +1]	UINT16	2
12	<b>06.0E.2B.34.01.01.01.0E.01.02.02.81.14.00.00</b>	CC Line_Num_Line - Samp_Num_Samp	CC A - E in Equation 7	[-1 ... +1]	UINT16	2
13	<b>06.0E.2B.34.01.01.01.0E.01.02.02.81.15.00.00</b>	CC Line_Num_Line - Samp_Num_Const	CC A - F in Equation 7	[-1 ... +1]	UINT16	2
14	<b>06.0E.2B.34.01.01.01.0E.01.02.02.81.16.00.00</b>	CC Line_Num_Line - Den_Line	CC A - G in Equation 7	[-1 ... +1]	UINT16	2
15	<b>06.0E.2B.34.01.01.01.0E.01.02.02.81.17.00.00</b>	CC Line_Num_Line - Den_Samp	CC A - H in Equation 7	[-1 ... +1]	UINT16	2
16	<b>06.0E.2B.34.01.01.01.0E.01.02.02.81.18.00.00</b>	CC Line_Num_Samp - Line_Num_Const	CC B - C in Equation 7	[-1 ... +1]	UINT16	2
17	<b>06.0E.2B.34.01.01.01.0E.01.02.02.81.19.00.00</b>	CC Line_Num_Samp - Samp_Num_Line	CC B - D in Equation 7	[-1 ... +1]	UINT16	2
18	<b>06.0E.2B.34.01.01.01.0E.01.02.02.81.1A.00.00</b>	CC Line_Num_Samp - Samp_Num_Samp	CC B - E in Equation 7	[-1 ... +1]	UINT16	2
19	<b>06.0E.2B.34.01.01.01.0E.01.02.02.81.1B.00.00</b>	CC Line_Num_Samp - Samp_Num_Const	CC B - F in Equation 7	[-1 ... +1]	UINT16	2
20	<b>06.0E.2B.34.01.01.01.0E.01.02.02.81.1C.00.00</b>	CC Line_Num_Samp - Den_Line	CC B - G in Equation 7	[-1 ... +1]	UINT16	2
21	<b>06.0E.2B.34.01.01.01.0E.01.02.02.81.1D.00.00</b>	CC Line_Num_Samp - Den_Samp	CC B - H in Equation 7	[-1 ... +1]	UINT16	2
22	<b>06.0E.2B.34.01.01.01.0E.01.02.02.81.1E.00.00</b>	CC Line_Num_Const - Samp_Num_Line	CC C - D in Equation 7	[-1 ... +1]	UINT16	2
23	<b>06.0E.2B.34.01.01.01.0E.01.02.02.81.1F.00.00</b>	CC Line_Num_Const - Samp_Num_Samp	CC C - E in Equation 7	[-1 ... +1]	UINT16	2
24	<b>06.0E.2B.34.01.01.01.0E.01.02.02.81.20.00.00</b>	CC Line_Num_Const - Samp_Num_Const	CC C - F in Equation 7	[-1 ... +1]	UINT16	2
25	<b>06.0E.2B.34.01.01.01.0E.01.02.02.81.21.00.00</b>	CC Line_Num_Const - Den_Line	CC C - G in Equation 7	[-1 ... +1]	UINT16	2
26	<b>06.0E.2B.34.01.01.01.0E.01.02.02.81.22.00.00</b>	CC Line_Num_Const - Den_Samp	CC C - H in Equation 7	[-1 ... +1]	UINT16	2
27	<b>06.0E.2B.34.01.01.01.0E.01.02.02.81.23.00.00</b>	CC Samp_Num_Line -	CC D - E in Equation 7	[-1 ... +1]	UINT16	2

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		Samp_Num_Samp				
28	<b>06.0E.2B.34.01.01.01.0E.01.02.02.81.24.00.00</b>	CC Samp_Num_Line - Samp_Num_Const	CC D - F in Equation 7	[-1 ... +1]	UINT16	2
29	<b>06.0E.2B.34.01.01.01.0E.01.02.02.81.25.00.00</b>	CC Samp_Num_Line - Den_Line	CC D - G in Equation 7	[-1 ... +1]	UINT16	2
30	<b>06.0E.2B.34.01.01.01.0E.01.02.02.81.26.00.00</b>	CC Samp_Num_Line - Den_Samp	CC D - H in Equation 7	[-1 ... +1]	UINT16	2
31	<b>06.0E.2B.34.01.01.01.0E.01.02.02.81.27.00.00</b>	CC Samp_Num_Samp - Samp_Num_Const	CC E - F in Equation 7	[-1 ... +1]	UINT16	2
32	<b>06.0E.2B.34.01.01.01.0E.01.02.02.81.28.00.00</b>	CC Samp_Num_Samp - Den_Line	CC E - G in Equation 7	[-1 ... +1]	UINT16	2
33	<b>06.0E.2B.34.01.01.01.0E.01.02.02.81.29.00.00</b>	CC Samp_Num_Samp - Den_Samp	CC E - H in Equation 7	[-1 ... +1]	UINT16	2
34	<b>06.0E.2B.34.01.01.01.0E.01.02.02.81.2A.00.00</b>	CC Samp_Num_Const - Den_Line	CC F - G in Equation 7	[-1 ... +1]	UINT16	2
35	<b>06.0E.2B.34.01.01.01.0E.01.02.02.81.2B.00.00</b>	CC Samp_Num_Const - Den_Samp	CC F - H in Equation 7	[-1 ... +1]	UINT16	2
36	<b>06.0E.2B.34.01.01.01.0E.01.02.02.81.2C.00.00</b>	CC Den_Line - Den_Samp	CC G - H in Equation 7	[-1 ... +1]	UINT16	2
37	<b>06.0E.2B.34.01.01.01.0E.01.02.03.01.00.00.00</b>	LDS Checksum	<b>This Key Defined in MISB EG 0601</b>	[0-65535]	UINT16	2

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## 5.4 Plane Reformatting Information Local Data Set

Table 5: Plane Reformatting Information LDS

Local Set Key		Name				
		Plane Reformatting Information LDS				
Constituent Elements						
Tag ID	Key	Name	Symbol/Notes	Units / Range	Format	Length
1	06.0E.2B.34.01.01.01.0E.01.02.02.81.2D.00.00	Plane X-scale Factor	a in Equation 10		FLOAT	4
2	06.0E.2B.34.01.01.01.0E.01.02.02.81.2E.00.00	Plane Y-scale Factor	b in Equation 10		FLOAT	4
3	06.0E.2B.34.01.01.01.0E.01.02.02.81.2F.00.00	Plane constant value	d in Equation 10		FLOAT	4
4	06.0E.2B.34.01.01.01.0E.01.02.02.81.30.00.00	Plane offset value	P <sub>OFF</sub> in Equation 9		FLOAT	4
5	06.0E.2B.34.01.01.01.0E.01.02.02.81.31.00.00	Plane Depth	D <sub>P</sub> in Equation 8		FLOAT	4
6	06.0E.2B.34.01.01.01.0E.01.02.03.01.00.00.00	LDS Checksum	This Key Defined in MISB EG 0601	[0-65535]	UINT16	2

**UNCLASSIFIED****5.5 Measured Data Format Floating Length Pack**

Table 6: Measured Data Values FILP

Local Set Key		Name				
		Measured Data Format FILP				
Constituent Elements						
Tag ID	Key	Name	Symbol/Notes	Units / Range	Format	Length
1	<b>06.0E.2B.34.01.01.01.0E.01.02.02.06.00.00.00</b>	Measurement Image Total Lines	This Key Defined in MISB EG 0801	[0-65535]	UINT16	2
2	<b>06.0E.2B.34.01.01.01.0E.01.02.02.07.00.00.00</b>	Measurement Image Total Samples	This Key Defined in MISB EG 0801	[0-65535]	UINT16	2
3	<b>06.0E.2B.34.01.01.01.0E.01.02.03.01.32.00.00</b>	Measurement Return Number	measurement_return_number	[0-255]	UINT8	1
4	<b>06.0E.2B.34.01.01.01.0E.01.02.03.01.33.00.00</b>	Measurement Bit Depth	As nb <sub>P</sub> in Equation 8	[0-255]	UINT8	1
5	<b>06.0E.2B.34.01.01.01.01.0E.01.02.03.01.34.00.00</b>	Array of measured data values		NA	NA	NA
6	<b>06.0E.2B.34.01.01.01.01.0E.01.02.03.01.00.00.00</b>	LDS Checksum	This Key Defined in MISB EG 0601	[0-65535]	UINT16	2

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## 5.6 Range Accuracy Data Format Floating Length Pack

Table 7: Accuracy Data Values FILP

Local Set Key		Name				
		Range Accuracy Data Values FILP				
Constituent Elements						
Tag ID	Key	Name	Symbol/Notes	Units / Range	Format	Length
1	06.0E.2B.34.01.01.01.01.0E.01.02.02.06.00.00.00	Accuracy Image Total Lines	This Key Defined in MISB EG 0801	[0-65535]	UINT16	2
2	06.0E.2B.34.01.01.01.01.0E.01.02.02.07.00.00.00	Accuracy Image Total Samples	This Key Defined in MISB EG 0801	[0-65535]	UINT16	2
3	06.0E.2B.34.01.01.01.01.0E.01.02.03.01.35.00.00	Accuracy Return Number	accuracy_return_number	[0-255]	UINT8	1
4	06.0E.2B.34.01.01.01.01.0E.01.02.03.01.36.00.00	Accuracy Bit Depth	accuracy_bit_depth	[0-255]	UINT8	1
5	06.0E.2B.34.01.01.01.01.0E.01.02.03.01.37.00.00	Array of accuracy data values		NA	NA	NA
6	06.0E.2B.34.01.01.01.01.0E.01.02.03.01.00.00.00	LDS Checksum	This Key Defined in MISB EG 0601	[0-65535]	UINT16	2

## 6 Appendix

This appendix gives detailed information on some of the reasoning for using the formulation defined in this Engineering Guideline.

### 6.1 Integer Mapping

The following integer to floating point mapping shall be used:

Let  $r_1$  be the lower bound of the floating point range. Let  $r_2$  be the upper bound. The openness or closed-ness of the bounds is irrelevant.

Define  $R = (r_2 - r_1)$ .

Let  $I$  be an integer represented in  $n$  bytes.  $I$  therefore can assume a value between 0 and  $2^{8n} - 1$ .

Let  $V$  be the value the floating point variable in the range  $r_1$  to  $r_2$  should assume given  $I$ .

$$V = r_1 + \left( I + \frac{1}{2} \right) \left( \frac{R}{2^{8n} - 1} \right) \quad \text{Equation 12}$$

The method of converting the original floating point value to an integer is not specified; under some circumstances it may be possible to create a more accurate final value for  $V$  by varying the encoding method from the straight inverse of the integer decoding method.

The same method can be used for variables that have reserved values. Some examples of such cases are the Not-a-Number and Infinity cases. The equation below gives a slight modification to Equation 12, where the variable  $m$  indicates the number of reserved items.

$$V = r_1 + \left( I + \frac{1}{2} \right) \left( \frac{R}{2^{8n} - 1 - m} \right) \quad \text{Equation 13}$$

This formulation assumes the reserved items are from zero to  $m-1$ .